

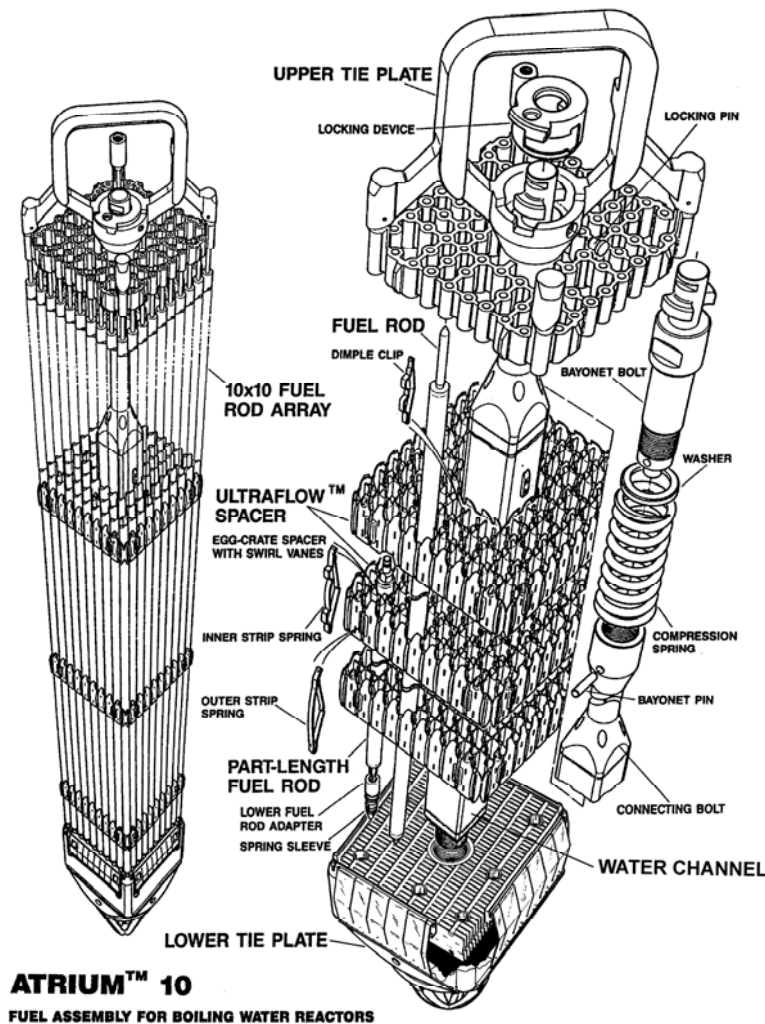
AREVA use of CFD in Fuel Assembly Design and Licensing

***Tom Keheley
Senior Expert, Thermal Hydraulics***

**Salt Lake City, UT
February 23/24, 2006**

CFD at the Areva US Fuels Group

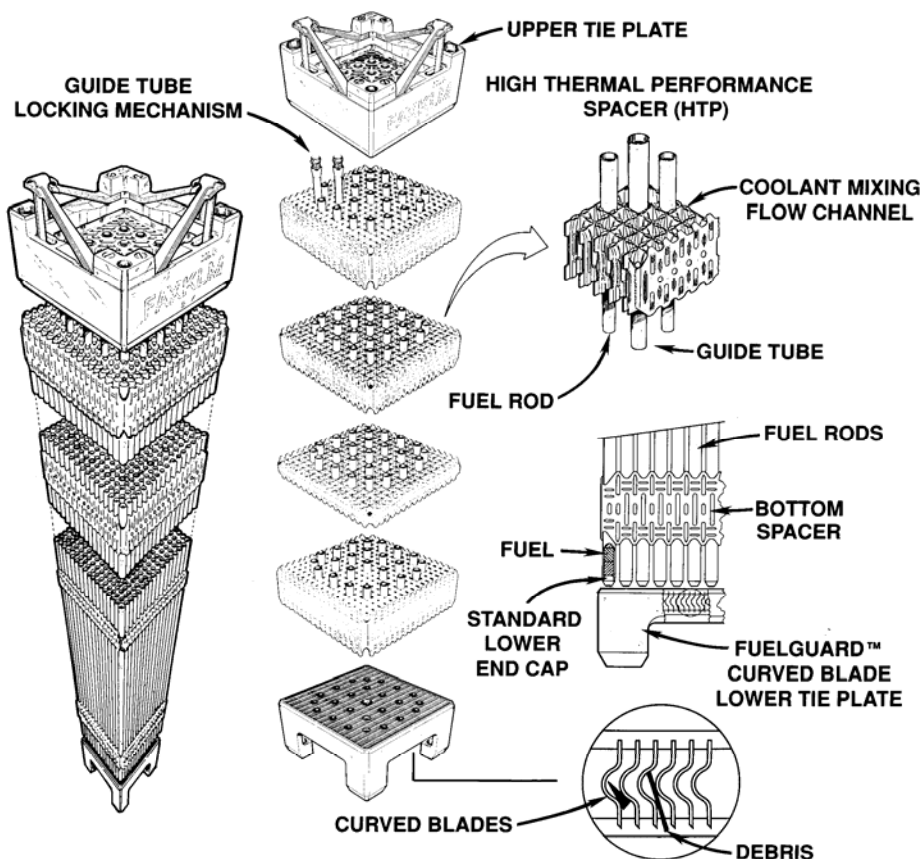
- > The Areva US Fuels Group is using STAR-CD to analyze and predict fuel assembly performance in single phase conditions**
- > We have 10 (1 64 bit machine and 9 32 bit machines) 2.8 GHz LINUX workstations networked together dedicated solely to CFD applications**
- > The choice of computer architecture, networking, and operating system was done in close cooperation with cd-adapco**



- > An ATRIUM-10 fuel assembly consists of 83 full length and 8 part length fuel rods in a 10x10 array
- > An internal water channel replaces a 3x3 array of rods
- > The assembly has 7 vaned ULTRAFLOW spacers in the heated length
- > The lower tie plate is a debris resistance FUELGUARD
- > The entire assembly is housed in a square channel

PWR Fuel Assembly

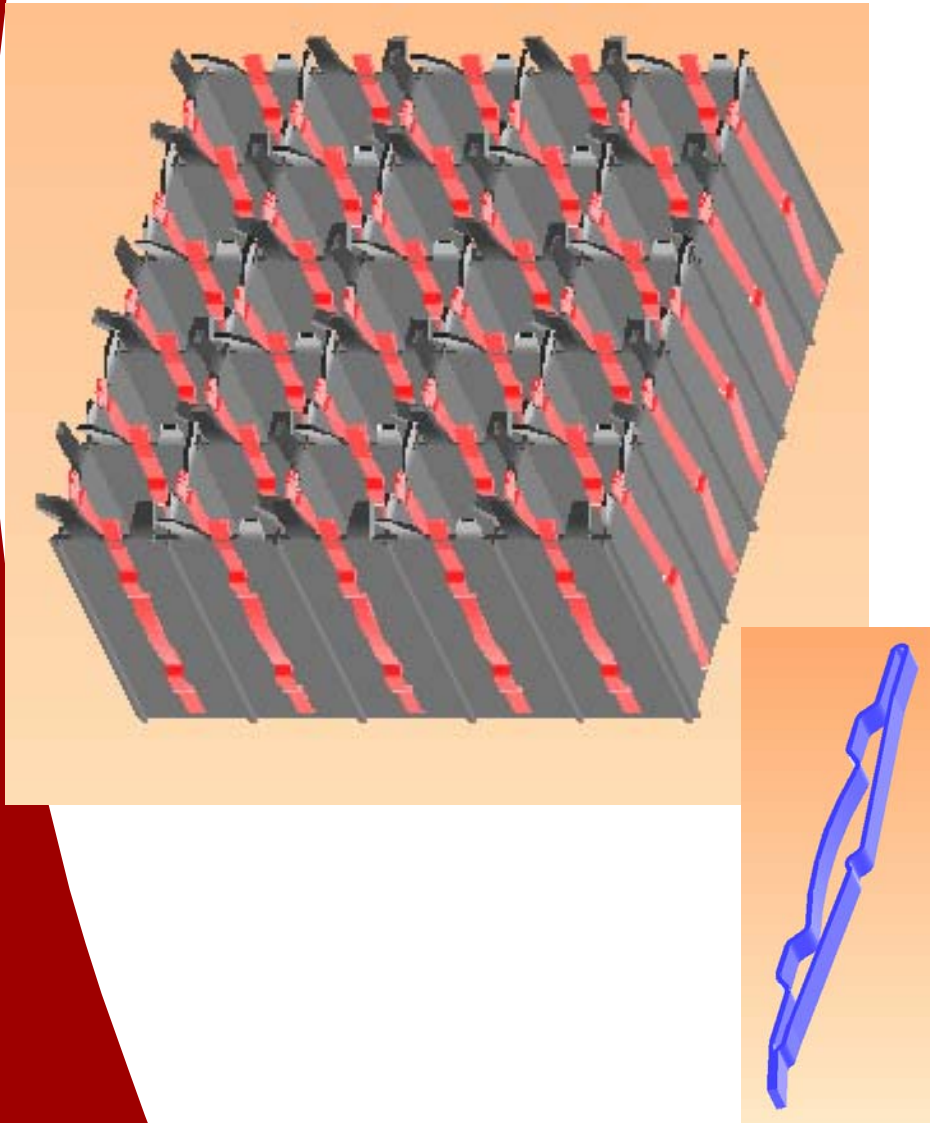
HTP 17x17 PWR FUEL ASSEMBLY



- > PWR fuel arrays vary from 14x14 to 18x18 and are not in channels
- > The spacers may be vaned or non-vaned
- > Normally there are 7 spacers to the heated length, but the upper portion of the bundle may contain Intermediate Flow Mixers

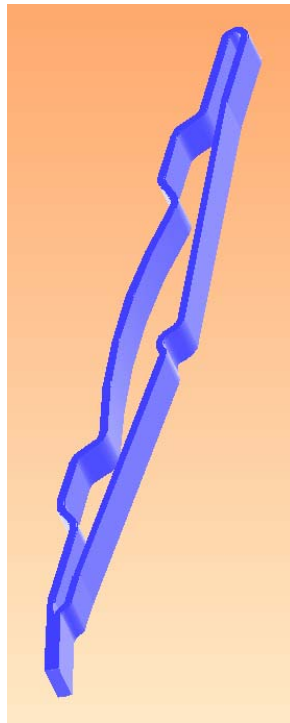
- > Areva has developed a set of best practices for meshing and modeling spacers**
- > These best practices were developed by benchmarking against LDV, pressure drop, and thermal mixing tests on about a dozen vaned and non-vaned spacer types**
- > The benchmarking demonstrated that it is necessary to include springs and dimples to accurately model the flow**

Spacer



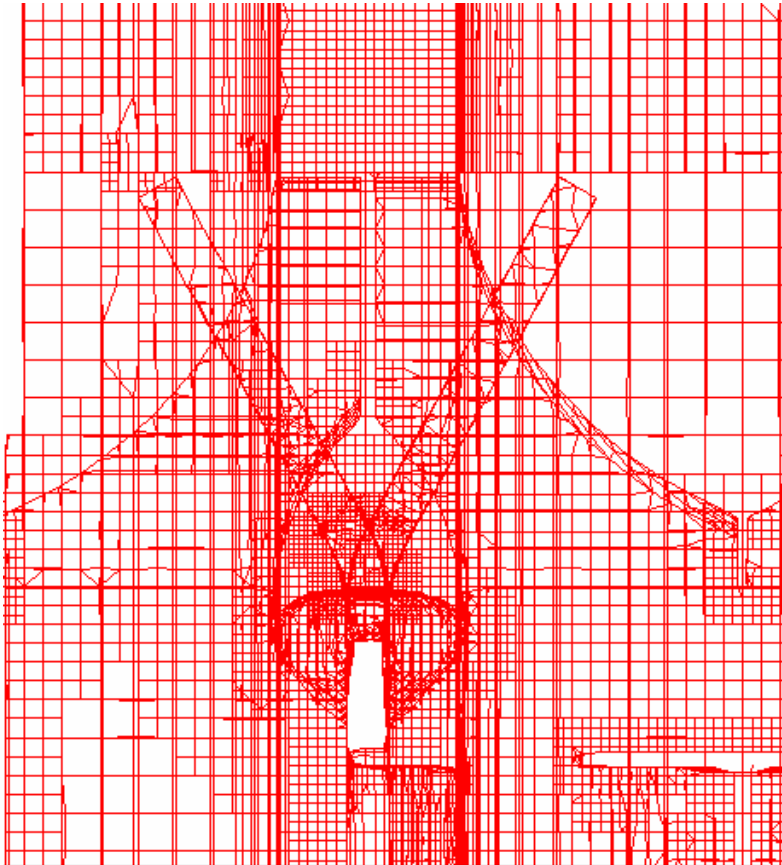
- > **Standard production models of the spacers can not be used to build the mesh**
- > **Strip cutouts such as slots for the joining of strips need special modification to eliminate gaps**
- > **Springs must be redesigned so that they are in their loaded condition**

Spacer Modeling



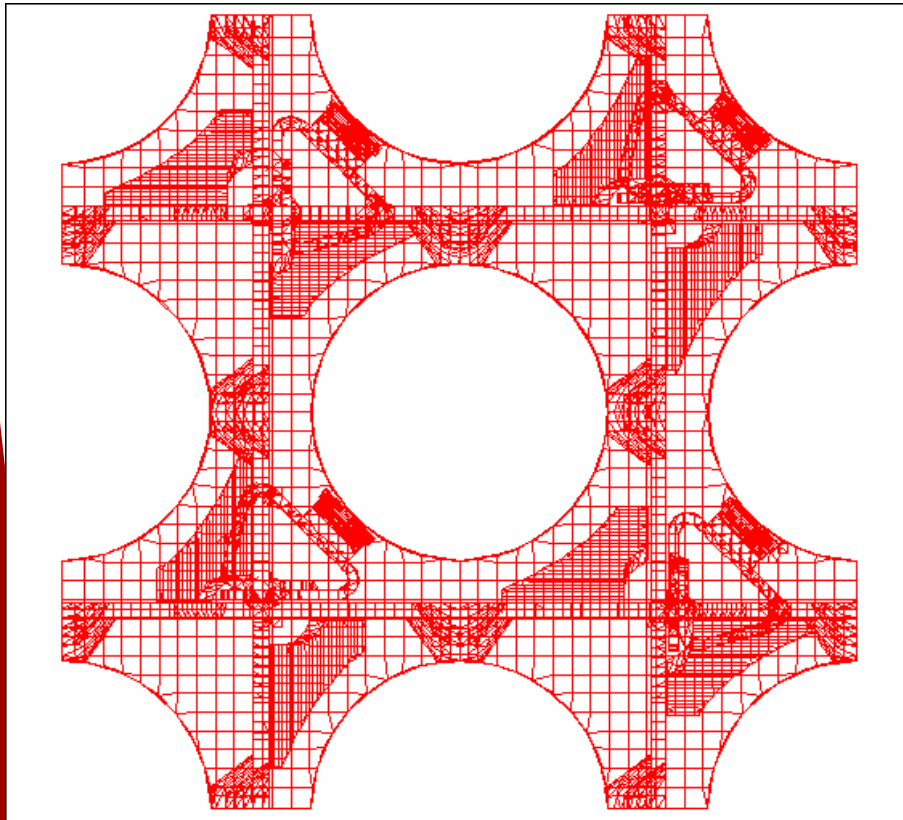
- > Springs must also be designed to be part of the spacer strip
- > The code will try to mesh any gap between the strip and spring
- > The spring usually is allowed to just penetrate the rod
- > Modifications to the production spacer model are quite intense and may take an experienced designer up to a week to complete

Spacer Modeling



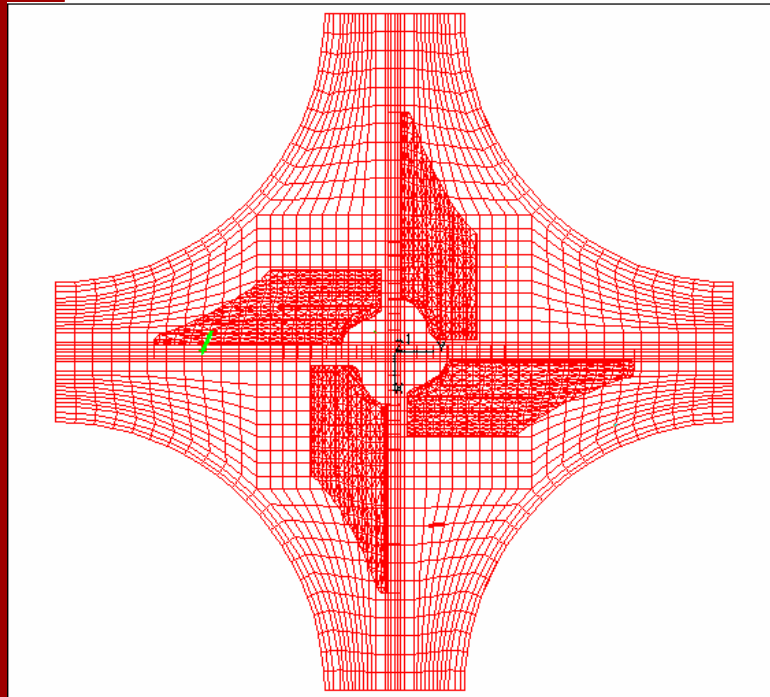
- > **It has been shown that for some spacer types modeling needs to be detailed enough to include weld nuggets**

Spacer Modeling



- > **The spacer itself is complex enough that a simple 2x2 subchannel mesh may take as long as a month to develop after the solid model is available**

Spacer Modeling



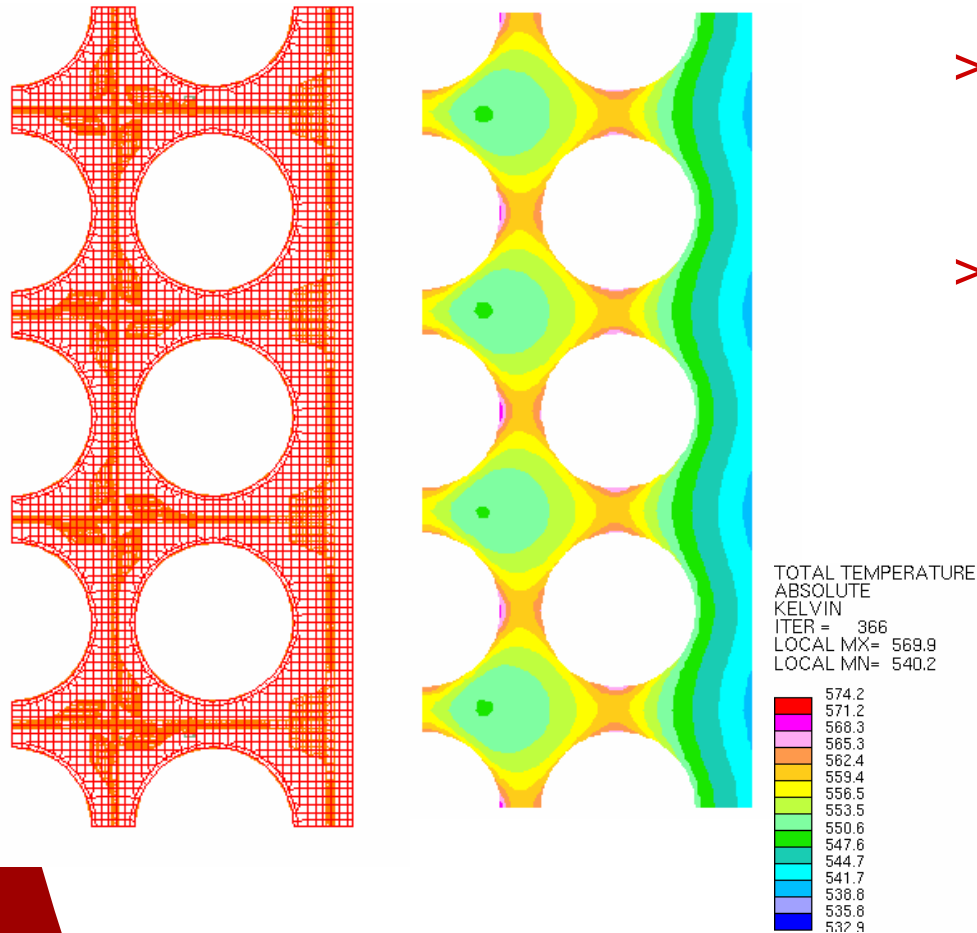
ULTRAFLOW SPACER
Thermal Mixing
 $v=5\text{m/s}$

STAR
D
pro-STAR 3.2
7-JUL-04
VIEW
0.000
0.000
1.000
ANGLE
0.000
DISTANCE
7.417
CENTER
0.000
0.000
240.000
QHIDDEN PLOT



- > It is not uncommon to use a fine mesh close to solid parts and larger mesh in the center of subchannels
- > Experience has shown that for spacer analysis the subchannel mesh size should be less than 1 mm to adequately measure the fluid rotation imparted by vanes or other design features

Spacer Modeling



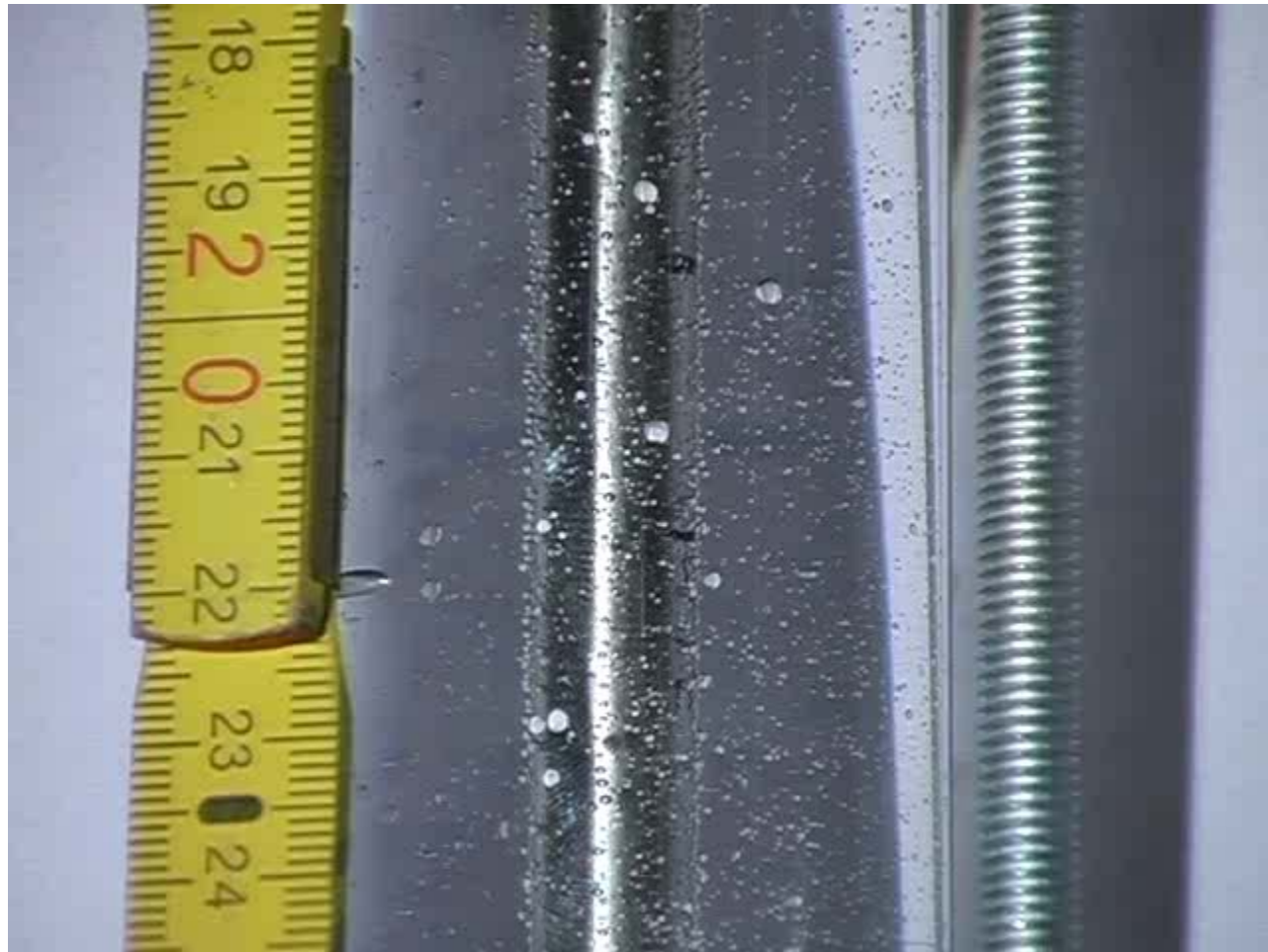
- > All spacer models shown so far are just the interior portion of the spacer
- > For BWR spacers, the peripheral row of rods need to include the side plate and channel wall

Spacer Modeling

- > So, as can be seen, to develop a simple 5x5 model of a fuel assembly and model only one of seven spacer pitches it can take over one month to model
- > The model will contain over 25 million cells
- > If it is analyzed using simple turbulence models and the SIMPLE solution scheme it will take over one week to reach convergence on ten computers
- > Changing to the PISO solution scheme or other turbulence models will add weeks to the required time

Spacer Modeling

- > It should be noted that to date this work has been directed to single phase, adiabatic modeling
- > As more two phase development takes place, these models need be included
 - ◆ PWRs normally operate in the bubbly flow regime
 - ◆ BWRs operate in the annular flow regime
- > The benchmarking will be repeated using two phase test results to verify the best practices are still applicable



Conclusions

- > A PWR fuel assembly may be as large as an 18x18 array**
 - ◆ Because they are not in fuel channels, flows may pass from one assembly to the other
 - ◆ Cold surfaces such as guide tubes, can effect the thermal hydraulic characteristics
- > BWR fuel assemblies are currently 10x10 arrays inside water channels**
 - ◆ These water channels effect the thermal hydraulics of the fuel assembly
 - ◆ Assembly lay out can effect subchannel flows and void distributions
- > Modeling a 5x5, single pitch, of a fuel assembly is currently at the limit of reasonable analysis**